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# *BLOOD LACTATE RESPONSE TO THE CF EXPRES STEP TEST: FINAL REPORT*

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## EXECUTIVE SUMMARY

The Canadian Forces (CF) personnel have their fitness measured by the EXPRES test. This test includes measures of strength, muscular endurance, aerobic power and body composition. Of the performance measures i.e., strength, muscular endurance and aerobic power, the first two are measured directly while the last is predicted or estimated from heart rate (HR) response to stepping activity. As a result of the prediction or estimate, error is introduced into the measure of aerobic power. The inaccuracies of the prediction could have adverse career action associated with it. The purpose of this study was to see if blood lactate could be used to more accurately predict maximal aerobic power.

Two-hundred and thirty five (235) CF male and female personnel performed the step-test procedures used to predicted maximal aerobic power. In addition to having their heart rates determined during the test, blood was sampled from a finger tip and analyzed for lactate (LA). A sub-sample of this population (n=156) also had their aerobic power measured directly during a maximal run performed on a treadmill. The HR and LA values measured during stage 5 of the stepping activity were compared in their ability to predict or estimate the aerobic power measured from the running performance. For the male subjects, LA predicted aerobic power better than HR; whereas, for the females, the prediction of aerobic power from LA and HR was similar.

It is feasible that LA could be used to evaluate fitness in CF personnel in the future. Considerations in arriving at such a decision include the following: lactate can be used to evaluate the intensity of a specific training program; the maximal aerobic power of specific populations cannot be evaluated using heart rate, LA offers a viable alternative for such populations; the cost effectiveness of LA analysis must be investigated. In the event that LA does prove to be an attractive fitness evaluation tool for the CF, this report provides a basis for evaluating the LA response to the exercise test which is presently used to evaluate aerobic fitness.

## ABSTRACT

This is the final report on the tasking to look at the blood lactate (LA) response to the Canadian Aerobic Fitness Test, i.e., EXPRES step test. The purposes of this study were to determine if LA could be used to predict maximal aerobic power ($\dot{V}O_2max$) from the EXPRES step-test procedures and to compare this prediction with the current procedures which employ submaximal heart rate (HR). Male (n=137) and female (n=98) CF personnel between the ages of 18 and 53 years participated in this study. The LA concentration after each stage of the step test was measured in all subjects by sampling blood from the finger-tip. A sub-sample of this population, 90 males and 66 females had their $\dot{V}O_2max$ measured directly during a maximal treadmill run. LA and heart rate (HR) from stage 5 were correlated with the treadmill-determined $\dot{V}O_2max$. At stage 5 the males ascend and descend a stairway consisting of 2 eight inch steps at a rate of 22 times per minute for 3 minutes; the females ascend and descend the same steps at 20 times per minute. The results showed increasing stages of the step test were associated with increasing LA. Correlations between LA and $\dot{V}O_2max$ were -0.71 and -0.72 for the males and females, respectively, and were higher than the correlations between HR and $\dot{V}O_2max$ which were -0.36 and -0.65 respectively. LA measured during stage 5 was a better predictor of $\dot{V}O_2max$ than heart rate for the males. For the females, although LA produced a higher correlation, it was not significantly different from HR. Age appears to be the main reason for the difference in LA response between males and females. Only 6% of the females tested were over 40 while 25% of the males exceeded this age.

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## INTRODUCTION

The Canadian Forces (CF) adopted the CF EXPRES test as the annual physical fitness testing procedure in 1983. This test is identical to the Canadian Standard Test of Fitness (1,2,3). The CF EXPRES test includes assessments of $\dot{V}O_2$max, muscular strength, muscular endurance, and body composition. $\dot{V}O_2$max is evaluated by the heart rate (HR) response to a step-test protocol. Hand grip strength is used as an index of total body strength. Muscular endurance is evaluated from sit-up and push-up performance. Body composition is assessed from skinfolds, circumferences, height, and weight measures. The results of the EXPRES test assume considerable importance especially when standards have been set that must be met. If these standards are not met the individual will be subjected to remedial physical training and potentially adverse career action. Thus the accuracy of the EXPRES test battery to measure specific fitness parameters and changes with fitness training should be precise. Strength and muscular endurance are measured directly, however, $\dot{V}O_2$max is predicted from the HR measured during the stepping activity. The test does not measure $\dot{V}O_2$max directly. It is, therefore, subject to error, exemplified by the moderate correlations reported between direct tests of $\dot{V}O_2$max and the step-test predicted values, r=0.67 to 0.82, (4,5). At best, 67% of the variance in directly measured $\dot{V}O_2$max among individuals can be explained by the predicted $\dot{V}O_2$max; in some subject samples only 45% of the variance is explained. For example, Bell and Allen (4) reported that for a directly measured $\dot{V}O_2$max value of 40 $ml \cdot kg^{-1} \cdot min^{-1}$ in a 30 y old male the step-test predicted value could range from 33 to 53 $ml \cdot kg^{-1} \cdot min^{-1}$, corresponding to the 5th and the 95th percentile of Canadian norms (2). In addition, the lack of sensitivity of the step test to directly measured training induced changes in $\dot{V}O_2$max (6) suggests that some other physiological indicator other than HR should be used to measure training response changes. Such potential errors in evaluation are obviously not acceptable when career action may be involved. Therefore, a more precise method of evaluating the ability to perform aerobic exercise other than heart rate would be advantageous.

It is known that blood lactate (LA) is an accurate means of assessing aerobic capacity and endurance performance (7,8,9,10). It was, therefore, believed that LA could be used in conjunction with the EXPRES test procedures to predict $\dot{V}O_2$max and that this prediction might be more accurate than the present technique which uses HR. In addition, LA has been shown to be sensitive to improvements in endurance fitness or aerobic capacity (7,11) which may not be the case for the step test (6). Moreover, the LA response at submaximal exercise is not affected to the same extent as is heart rate by certain pharmacological agents i.e., β-adrenergic blockers (12). This factor is particularly noteworthy considering the significant number of CF personnel who are treated for hypertension or migraines with blocking agents. Such drug treatment invalidates the value of $\dot{V}O_2$max determined from the EXPRES step-test because of the marked effect on heart rate.

Therefore, this study was undertaken to determine the LA response to the CF EXPRES step-test, and to compare the predictions of $\dot{V}O_2$max using the standard heart rate protocol to those using the LA response to the same step-test.

## METHODS

*Subjects*

Two hundred and thirty-five CF personnel (137 males and 98 females) aged 18-53 years, participated in the study. These personnel were selected from various Canadian Forces bases (i.e. Calgary, Kingston, Ottawa, Toronto and Trenton). They represented a wide spectrum of age, and physical fitness levels. The physical characteristics of all the subjects, including their predicted and directly measured $VO_2$max, are presented in Table 1.

Table 1: Physical characteristics of the subjects who participated in the EXPRES step test and the maximal treadmill test. Values are mean ±SD

| | Step Test | Treadmill | Step Test | Treadmill |
|---|---|---|---|---|
| | males | males | females | females |
| | (n=137) | (n=90) | (n=98) | (n=66) |
| Age (y) | 31.4 ±8.4 | 29.5 ±8.2 | 30.6 ±6.5 | 30.0 ±6.3 |
| Weight (kg) | 78.9 ±11.5 | 79.2 ±11.9 | 65.2 ±9.1 | 64.4 ±8.0 |
| Predicted $\dot{V}O_2$ max* ($ml \cdot kg^{-1} \cdot min^{-1}$) | 40.1 ±4.3 | 40.5† ±4.1 | 33.5 ±3.0 | 33.9† ±3.2 |
| Measured $\dot{V}O_2$ max** ($ml \cdot kg^{-1} \cdot min^{-1}$) | - | 49.4 ±8.8 | - | 39.1 ±6.6 |

* Predicted from step test results.

** Measured from treadmill test.

† Predicted significantly lower than measured value.

*Test Procedures*

Before commencing the various tests, each subject completed the Physical Activity Readiness Questionnaire, PAR-Q, (13) and signed an informed consent form. Each subject performed the step-test as described in the CF EXPRES "manual" (14); however, to obtain sufficient lactate data at the lower stages of the step-test, 180 individuals or over 75% of the group commenced stepping at stage 2. Those individuals over 50 had the option of starting at stage 1 or 2. At stage 2 the males and females ascended and descended a stairway consisting of two 8 inch high steps at a rate of 14 times per minute for three minutes. Thereafter the stepping rate was increased. At stage 3&4 the rate of ascent and descent was 17&19 times/minute respectively for both sexes. At stage 5, the rate increased to 22 for the males and 20 for the females. At stage 6, the rate for the males

was 24 for the females 22. Immediately upon completion of each stage heart rate was measured for ten seconds, as per the testing protocol, and a 20 µl capillary blood sample was taken from a finger prick. The subjects were allowed to progress to the next stage as long as their heart rate was at or below the heart rate guidelines described in the CF EXPRES (14). Based on the heart rate measured during the maximum allowable exercise stage, their $\dot{V}O_2$max was predicted using the CF EXPRES aerobic calculator.

The blood taken after each stage of exercise was immediately expelled into 200 µL of cold 0.4 M perchloric acid and stored on ice. All samples were stored at -80°C until assayed for their lactate concentration (15).

Over 65% (156 personnel) volunteered to perform a $\dot{V}O_2$max test on the treadmill. Heart rate was monitored with either a sport tester (Polar®) or via electrocardiograph (Cardisuny® model 501D) from bipolar ECG leads. Oxygen consumption, carbon dioxide production and ventilation were monitored with an automated metabolic cart system (Alpha 4400 Technologies®, Horizon Sensormedic® or an in house system composed of Ametek® $O_2$ and $CO_2$ analysers, Alpha Technologies® ventilation module and Hewlett Packard desk-top computer). After a 2 min familiarization walk at 4.8 km/hr, a continuous protocol of progressively increasing speed and grade was utilized to reach the subject's $\dot{V}O_2$max. $\dot{V}O_2$max was defined by a plateau in oxygen consumption with an increasing minute ventilation or by subject volitional fatigue. The highest value in oxygen consumption measured during the test was considered as the $\dot{V}O_2$max.

*Treatment of Data*

Standard statistical measures were used to determine the means and standard deviations. Pearson product moment correlations were used to determine "r" values. A two-tailed test was used to evaluate the significance of the correlation. A Familywise correction (16) was applied to each column of Table 3 to obtain a true 0.05 significant level. The Fisher's z transformation (17) was used to determine if the LA and HR correlations were significantly different from each other. A paired t-test was used to compare predicted vs measured $\dot{V}O_2$max. Stepwise regression analysis was used to determine which variables contributed significantly to the prediction of $\dot{V}O_2$max. Except for the Familywise (16) and Fisher Z transformation (17), all statistical processing was performed using BMDP software (18). Significance was set at the 0.05 level.

## RESULTS & DISCUSSION

One purpose of this study was to examine the feasibility of using the LA response to the EXPRES step-test to evaluate aerobic fitness. Table 2 describes the LA response to the stepping exercise (means ±SD and range of values) at each stage of the EXPRES test for both the male and female subjects. It is apparent from the LA response that the stepping exercise, although submaximal in intensity, is sufficient to markedly raise LA levels. The range of LA concentrations measured indicates that the EXPRES raises lactate values sufficiently so that they can be within the 2-5 mM range. This range has been earlier demonstrated to be appropriate to predict endurance performance (7,8,19). It, therefore, appears feasible that LA measures could be used in conjunction with the CF EXPRES step-test without altering the test protocol to evaluate aerobic fitness of CF personnel.

This study was also undertaken to compare the strength of the prediction of $\dot{V}O_2max$ determined by heart rate with that determined by LA. Table 3 describes the Pearson product moment correlations among the treadmill determined value of $\dot{V}O_2max$ and the normal variables used in the prediction of $\dot{V}O_2max$ and LA for the different male and female samples at stages 4, 5 and 6.

Table 2: Blood lactate ($mmol \cdot L^{-1}$) at each stage of the step test. Values are mean ±SD.

| Stage | No. of Samples | | Lactate | | Range | |
|---|---|---|---|---|---|---|
| | males | females | males | females | males | females |
| pre | 93 | 77 | 1.85 ±0.66 | 1.50 ±0.49 | 0.77-3.87 | 0.51-3.29 |
| 2 | 99 | 81 | 1.62 ±0.80 | 1.61 ±0.60 | 0.56-4.84 | 0.55-3.91 |
| 3 | 135 | 96 | 1.65 ±0.93 | 1.86 ±0.87 | 0.47-4.55 | 0.63-5.01 |
| 4 | 136 | 95 | 1.92 ±1.13 | 2.41 ±1.09 | 0.49-5.25 | 0.77-5.40 |
| 5 | 112 | 65 | 2.64 ±1.46 | 2.65 ±1.14 | 0.96-6.91 | 1.08-5.78 |
| 6 | 72 | 31 | 3.02 ±1.33 | 3.18 ±1.32 | 1.31-5.60 | 0.89-6.84 |

Table 3: Pearson product moment correlations among the measured $\dot{V}O_2max$ and the step test measures at stages 4, 5 & 6 and Blood Lactate.

| Variable | Stage 4 | | Stage 5 | | Stage 6 | |
|---|---|---|---|---|---|---|
| | males | females | males | females | males | females |
| Number | 90 | 66 | 78 | 53 | 53 | 27 |
| Lactate | -0.60 | -0.56 | -0.71 | -0.72 | -0.68 | -0.68 |
| Age | -0.63 | -0.05* | -0.61 | 0.01* | -0.56 | 0.05* |
| Weight | -0.21 | -0.33 | -0.22* | -0.31* | -0.12* | -0.54 |
| Stage Heart Rate | -0.30 | -0.64 | -0.36 | -0.66 | -0.18* | -0.54 |

* not significant beyond 0.05 level, all the rest of values are significant.

The data from stages 4, 5, and 6 are analyzed as these are the stages where personnel usually have there fitness evaluated. Different numbers or degrees of freedom are used in the correlations between treadmill $\dot{V}O_2$max and the various variables because fewer subjects reached the higher stages. At stages 5 and 6 LA produced the highest correlation with $\dot{V}O_2$max. Although LA was significantly better than HR for predicting $\dot{V}O_2$max at stages 5 ($t=4.42$, $p<0.005$) and 6 ($t=4.57$, $p<0.005$) for the males, it was not significantly better than HR at either stage 5 ($t=0.82$, $p>0.05$) or stage 6 ($t=0.61$, $p>0.05$) for the females.

The difference between the males and females appears to be age-related. For the males, age was significantly related to the measured $\dot{V}O_2$max, whereas for the females, no relationship was found (Table 3). Further, the males had the greater range in age, i.e., from 18-53 and 24.8% of the male subjects were over 40 years old. The females ranged in age from 18-45 and only 6% of the female sample was over 40. When the males over 40 were removed from the analysis at stage 5, the correlation between LA and $\dot{V}O_2$max and age and $\dot{V}O_2$max decreased to $r=-0.64$ and $r=-0.42$ respectively. However, the LA correlation was still significantly higher than the correlation between HR and $\dot{V}O_2$max which was $r=-0.25$, ($t=3.17$, $p<0.005$). This is not consistent with the female results which suggest that LA and HR predict $\dot{V}O_2$max equally well for individuals under forty.

Tables 4 and 5 show the multiple correlations derived from a stepwise regression to predict treadmill $\dot{V}O_2$max for the males and females, respectively. Only the data for the subjects who completed both the CF EXPRES test at stage 5 and the maximal treadmill test were used. The independent variables used in the regression included LA plus the three other variables normally used in the CF EXPRES, i.e., stage HR, age, and weight. The variables are entered or removed according to their ability to predict treadmill $\dot{V}O_2$max. The multiple R is reported as each variable is added into the prediction. For the males, the greatest proportion of the variance comes from LA with age being the only other variable that contributes significantly to the variance. For the females, LA agains accounts for greatest proportion of the variance, however, both HR and weight also contribute significantly to the variance.

Table 4: Multiple correlations (R) from stepwise regression for predicting directly measured $\dot{V}O_2$max from step test variables and lactate at stage 5 for CF males.

| Variable | R | $R^2$ | $\Delta R^2$ | $F(\Delta R^2)$ |
|---|---|---|---|---|
| Lactate | 0.710 | 0.504 | 0.504 | 27.85 |
| Age | 0.761 | 0.579 | 0.075 | 11.53 |
| Weight | 0.764 | 0.584 | 0.005 | 0.90 |
| Heart rate | 0.764 | 0.584 | 0.000 | 0.03 |

Table 5: Multiple correlations (R) from stepwise regression for predicting directly measured $\dot{V}O_2max$ from step test variables and lactate at stage 5 for CF females.

| Variable | R | $R^2$ | $\Delta R^2$ | $F(\Delta R^2)$ |
|---|---|---|---|---|
| Lactate | 0.724 | 0.524 | 0.524 | 20.22 |
| Heart rate | 0.809 | 0.654 | 0.130 | 24.41 |
| Weight | 0.829 | 0.687 | 0.033 | 4.84 |
| Age | 0.835 | 0.696 | 0.009 | 1.53 |

The multiple linear regression equation to predict $\dot{V}O_2max$ from LA without using HR is shown below for the males and females.

Male equation:

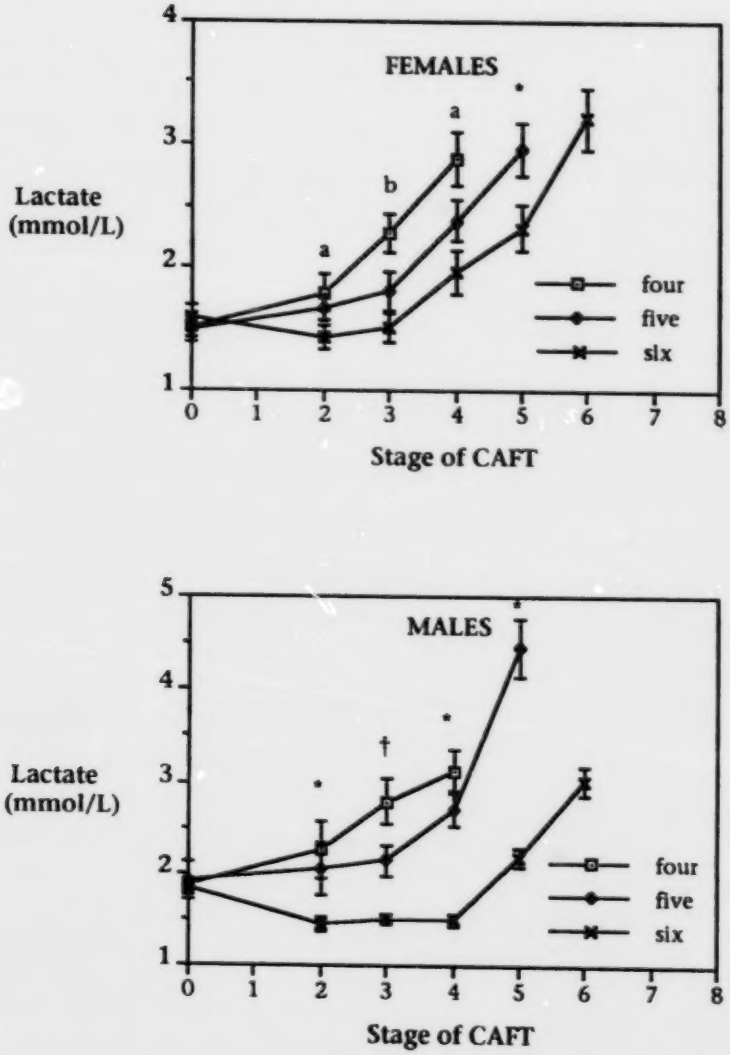
$$\dot{V}O_2max = 69.4 - 0.36 \cdot age - 3.62 \cdot LA \ (r=0.76)$$

Female equation:

$$\dot{V}O_2max = 54.5 - 0.06 \cdot wt - 4.01 \cdot LA \ (r=0.73)$$

where age is in years, wt is weight in kilograms and LA is the blood lactate concentration in $mmol \cdot L^{-1}$. The equation for the males could be used on most CF male personnel, but should be validated on another sub-sample of the CF male personnel. The female equation could only be used on those CF females below the age of 45 years and again should be validated on another sub-sample of the CF female population. However, the moderate correlations obtained from LA for the male and female personnel suggest that the effort required to sample and analyze LA may outweigh potential benefits.

The present study was undertaken to assess whether LA was a better predictor of $\dot{V}O_2max$ than HR. Although the results do not strongly support abandoning the current CF procedures, other factors that do support the use of LA rather than HR need to be discussed and should be considered for future tasking by DPERA. For example, initial lactate levels averaged 1.85 and 1.50 $mmol \cdot L^{-1}$ for the males and females, respectively. These concentrations are quite high for resting values, which suggests these subjects did not come to the test site in a normal rested state. They must have been involved in some other activity or exercise prior to the test which is contraindicated in the EXPRES guide lines (14). It is known that previous exercise adversely affects submaximal HR. Although the subjects' pre-exercise heart rates were sufficiently low indicating that they could proceed with the step-test, the high resting lactate levels indicated otherwise. The males and females who performed a treadmill test and reached stage 5 support this fact; their




six, individuals who did stages 2-6 only
five, individuals who did stages 2-5 only
four, individuals who did stages 2-4 only

Figure 1. Lactate concentration at the different stages of the step test for 3 sub-groups from the male and female population.
a four different from six.
b four different from other groups.
* six different from other groups.
† all groups different from each other.

predicted values, males (43.1) and females (35.2) were significantly lower than their measured values, males (49.8) and females (40.0). On the other hand, the predicted $\dot{V}O_2$max values from the lactate equations mentioned above, for the males (49.9) and females (40.1), were similar to their measured $\dot{V}O_2$max values.

Moreover, when the normal step-test procedures are used, the high resting lactate values are compensated for. The lower stages will allow the resting excess lactate to be metabolized. This is shown in Figure 1 which depicts the lactate concentrations at the various step-test stages for three sub-groups of the male and female sample: those that completed up to stage 4 (four), 5 (five), and 6 (six). The group labelled six were the fittest individuals. These fitter individuals showed the expected reduced lactate response to similar work loads when compared with the other groups, and also showed that the initial high resting LA levels were compensated for as the individual progressed to the higher stages. It also shows the curves typically seen for lactate during progressively increasing treadmill or bicycle exercise (20,21).

A further conclusion can also be drawn from Figure 1. The step test accurately grouped subjects if the LA were used as a validation criteria. This is especially true once the higher stages were reached. Furthermore, the higher stages produced the best correlation between LA and $\dot{V}O_2$max (Table 3). If stage 5 were to be used as the testing level, then it is recommended that all subjects commence stepping activity at stage 3. This will ensure the best results for the prediction from LA.

Another factor previously mentioned lends credibility to the use of LA. There is a small but significant proportion of the CF personnel who are presently not tested because they are being treated with β-blockers. These drugs are used to control hypertension and migraine headaches. Beta-blockers cause a moderate decrease in blood pressure, a pronounced reduction in heart rate, and a slight decrease in cardiac output (22,23,24,25,26). Given the reduction in HR, the prediction of $\dot{V}O_2$max from heart rate of personnel treated with β-blockers therapy is invalid. β-blockers do not markedly affect the LA response to exercise during submaximal exercise of short duration, less than 15 minutes (12). This suggests that the LA response could be used with the step-test procedures to analyze the fitness level of those individuals being treated with β-blockers.

Finally, and perhaps most importantly, $\dot{V}O_2$max is used as the criterion measure in the CF for cardiovascular fitness. Most activities performed by CF personnel, however, demand submaximal rather than maximal energy expenditures. Defining cardiovascular fitness only in terms of $\dot{V}O_2$max assumes that expressing the energy expenditure as a percentage of $\dot{V}O_2$max (i.e., %$\dot{V}O_2$max) normalizes differences in submaximal performance. There is an increasing body of evidence that documents that a blood lactate-related variable is a better predictor of submaximal endurance performance than $\dot{V}O_2$max (7). Also, it is well established that the LA response to exercise following an endurance training programme can change independently from the change in $\dot{V}O_2$max (7,8,10,20,27,28,29). This means that submaximal performances can increase more than $\dot{V}O_2$max and the prediction of $\dot{V}O_2$max from the EXPRES test would not reflect these improvements in performance. Two examples are given below to illustrate the above discussion.

Example 1. Two individuals are asked to perform a task that demands a $\dot{V}O_2$ of 30

$ml \cdot kg^{-1} \cdot min^{-1}$. For one person, this activity represents 50% of his $\dot{V}O_2max$ (which is 60 $ml \cdot kg^{-1} \cdot min^{-1}$) and for another individual this activity represents 60% of his $\dot{V}O_2max$ (which is 50 $ml \cdot kg^{-1} \cdot min^{-1}$). If $\dot{V}O_2max$ was the most important determinant of submaximal performance, one would conclude that the first individual with the higher $\dot{V}O_2max$ (and exercising at 50% $\dot{V}O_2max$) would perform longer than the second person. However, if additional information were available that revealed an important LA variable occurred at 50% $\dot{V}O_2max$ for the first individual and 60% $\dot{V}O_2max$ for the second person, one would observe no difference in the performance of this activity between these two individuals.

Example 2. Following a 3-month endurance training programme, an individual's $\dot{V}O_2max$ has not changed from his pretraining value of 45 $ml \cdot kg^{-1} \cdot min^{-1}$. However, his ability to perform a task requiring a $\dot{V}O_2$ of 30 $ml \cdot kg^{-1} \cdot min^{-1}$ (or 75% $\dot{V}O_2max$) has improved by 20%. Subsequent evaluation reveals that a specific LA variable that occurred at 50% $\dot{V}O_2max$ before training occurs at 60% $\dot{V}O_2max$ after the training programme. This represents a 20% increase in the $O_2$ equivalent of this lactate variable which parallels the improvement in submaximal performance.

In summary, in those situations where fitness levels are important to career progress such as in the CF, the present report indicates that the measure of LA would enhance the prediction of aerobic power and would reflect training induced changes better than the present system. In addition the use of LA would possibly save the CF thousands of man hours with regards to re-evaluation and remedial training. Plus it could be used to evaluate the fitness level of a sub-sample of the CF that was not previously available for testing, i.e., those individuals on β-blockers. The techniques and procedures for measuring LA in the field situation may seem a little extensive; however, when maximal treadmill testing is the alternative, a strong case can be made for the LA measure. The procedures for blood sampling and analysis are simple. The cost of the equipment is moderate and the maintenance of the equipment is minimal.

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This is the final report on the tasking to look at the blood lactate (LA) response to the Canadian Aerobic Fitness Test (CAFT). The purposes of this study were to determine if LA could be used to predict maximal aerobic power ($VO_2max$) from the EXPRES step-test procedures and to compare this prediction with the current procedures which employ submaximal heart rate (HR) . Male (n=137) and female (n=98) CF personnel between the ages of 18 and 53 years participated in this study. The LA concentration after each stage of the CAFT was measured in all subjects by sampling blood from the finger-tip. A sub sample of this population, 90 males and 66 females had their $VO_2max$ measured directly during a maximal treadmill run. LA and heart rate (HR) from stage 5 were correlated with the treadmill determined $VO_2max$. The results showed increasing stages of the CAFT were associated with increasing LA. Correlations between LA and $VO_2max$ were -0.71 and -0.72 for the males and females, respectively, and were higher than the correlations between HR and $VO_2max$ which were -0.36 and -0.65 respectively. LA measured during stage 5 was a better predictor of $VO_2max$ than heart rate for the males. For the females, although LA produced a higher correlation, it was not significantly different from HR. This difference in LA response between males and females is probably age related. Only 6% of the females tested were over 40 while 25% of the males exceeded this age. Moreover, when the older males were removed from the analysis, the correlation between LA and VO2max was -0.50 and this value was still significantly different than the relationship between HR and $VO_2max$ (r=-0.25).

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EXPRES TEST, LACTATE, MAXIMAL AEROBIC POWER, PHYSICAL FITNESS